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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

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☐ *Additional inventors are being named on the _____ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

DISTRIBUTED BEACONING PERIODS WITH MODIFIED SLOTTED ALOHA CHANNEL ACCESS

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ENCLOSED APPLICATION PARTS ***(check all that apply)***

☒ Specification *Number of Pages* 5 ☐ CD(s), Number

☐ Drawing(s) *Number of Sheets* ☐ Other (specify)

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ Applicant claims small entity status. See 37 CFR 1.27.

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FILING FEE AMOUNT ($)

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____.

Respectfully submitted,

SIGNATURE _______________

Date 24 March 2004

REGISTRATION NO.: 36,299
(if appropriate)

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USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

Detailed description of the invention

Summary

This invention provides an efficient way to make a reservation of transmission capacity and to keep this reservation during the lifetime of the connection. The Philips Distributed Reservation Protocol has been selected by the Multi-Band OFDM Alliance (MBOA) as the new MAC protocol for UWB. However, the Philips Beacon Collision Resolution Protocol has not been adopted. Instead, it has been decided to make a reservation by randomly accessing reservation slots in one or several reservation periods.

This way of announcing reservations has the disadvantage that a device has to repeatedly access the medium in a random access manner, as the reservation has to be announced to the neighboring stations in each superframe.

In the present invention it is foreseen that each device not only keeps a table of all occupied data slots in the superframe but also of all occupied reservation slots. The slotted Aloha access is only carried out when a reservation is carried out for the first time. The random access is only carried out over all unoccupied reservation slots. Once a reservation has been successfully established, the reservation slot is kept.

Background of the invention

The Multi-Band OFDM Alliance (MBOA) has selected a merged proposal of Philips and Alereon (and Sony) as the new MAC protocol for UWB. The merged proposal is very similar to the original Philips proposal. However, a few modifications have been applied to deal with the concerns of Alereon. The original Philips distributed MAC protocol is described in [1-3]. A brief overview of the MAC protocol is given in the following.

The time is divided into superframes, as shown in Figure 1. At the beginning of each superframe there is a beacon period followed by a data transmission phase.

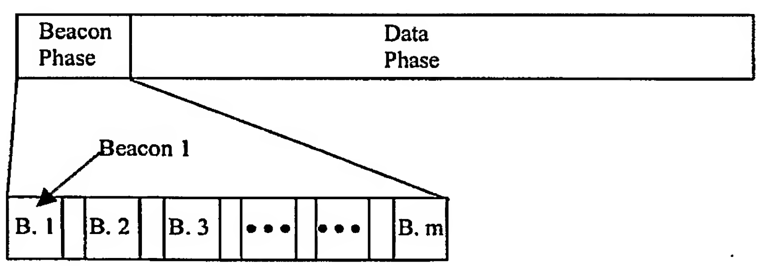

Figure 1: Superframe layout

In the data phase two access mechanisms are possible. One access method is called "Distributed Reservation Protocol" (DRP). It foresees that devices can make a reservation for a certain period of the data phase. The reservation is negotiated between sender and receiver(s) of the planned transmission. This negotiation is either carried out by a dedicated signalling handshake, or implicitly by including the reservation information in the sender and receiver(s) beacons. Once the reservation is established, the reservation information has to be included in the beacon of sender as well as receiver(s) in every superframe, in which the reservation is still active. This is necessary in order to inform neighboring devices of sender and receiver(s) about the existing reservation. No other device

beside the sender(s) is allowed to access the medium at the beginning of a reserved period. In order to make efficient usage of unused reservation periods, two type of reservations are defined: soft and hard reservations. In a soft reservation period other devices can access the medium after a certain idle time on the medium. In a hard reservation other devices are only allowed to access the medium after the sender(s) and receiver(s) have signalled the end of their transmission(s) by a NAK-RTS / NAK-CTS signalling handshake.
The second possible access method is the Enhanced Distributed Coordination Function (EDCA) of IEEE 802.11e, which is based on Carrier Sense Multiple Access (CSMA) with back-off protocol. This random access method is only allowed in non-reserved parts of the data phase or in unused reservation periods. Reservations have to be respected by all devices.
In the original Philips proposal beacons are used to signal reservations as well as for power save purposes. Each device sends it own beacon in a fixed beacon slot. The device selects its slot among the unused slots of a reservation period after it has been turned on. In order to detect that two devices have selected the same beacon slot, each device includes in its own beacon information about all other beacons that it has received. A device can detect that its beacon has eventually collided with another device's beacon by the fact that its beacon is not referenced in any beacon of the other devices. In this case the device has to randomly select a different beacon slot in the next superframe.
The Philips Beacon Collision Resolution Protocol (BCRP) described above has been rejected by Alereon. This is why it is not included in the merged proposal for the UWB MAC. Instead it has been decided to transmit beacons using EDCA or Slotted Aloha
Both approaches have several disadvantages, which are described in the following section. In order to circumvent these disadvantages a new beacon access protocol is proposed in this invention.

Another drawback of existing protocol is that only allows for one single Beaconing Period (BP) fixed to 64 slots, introducing some scalability limitations. Moreover, when new devices, using a different BP, come into range of existing devices, the BPs need to be re-aligned and synchronized into one single BP, creating a transition state that may cause some communication disruption. In order to solve these two problems, Distributed Beaconing Periods are proposed.

References:

[1] Beaconing Protocol for Ad-Hoc Networks, ID Number: 779458

[2] Distributed Reservaton Protocol, ID Number: 299284

[3] Enhanced NAV mechanism for optimal reuse of the spectrum, ID Number: 779489

Problems or disadvantages overcome by the invention

EDCA, a contention based access, introduces random delays in the transmission of beacons. These delays limit the benefits of devices using power management schemes. That is, devices that wake up to receive the beacons from neighbours, do not exactly know when the beacon are going to be sent, and therefore need to remain awake for an undetermined period of time. Moreover, if EDCA is used, there is a certain probability that beacons collide (with other beacons, or any other transmission), and therefore, reception of beacons is not guaranteed. In addition, the sender(s) of beacons(s) do not get any feedback from the receiver(s), and therefore there is no possibility for the sender(s) of the beacon(s) to detect that their beacons have collided.

A pure slotted Aloha random access in the beacon slots has also several disadvantages. One problem is also related to the missing feedback whether a reservation attempt has been successful or not. In case of a collision of a beacon with the beacon of another device, there is no possibility for the sender(s) of the beacon(s) to detect that their beacons have collided. This is due to the fact that the beacons of neighboring devices are no longer reported in a beacon, as Philips had proposed originally. The only possibility to detect that a reservation overlapping with the own reservation had been announced in the colliding beacon is a missing reference to the reservation in the beacon of the receiver. However, the receiver beacon might have been sent before the sender beacon, in which case the sender has no possibility to detect the reservation collision at all. The data transmitted during the reserved period (which could be very long) would be lost.
Another problem of the pure slotted Aloha access is that every device would have to contend for the beacon slots perpetually in every superframe, because the reservation information has to be announced in every superframe. Of course one could apply the rule that reservations of other devices are assumed to be still active, even if no beacon of this device was received in the current superframe. This would guarantee that reservations are still respected even if a beacon is lost. However, in order to support device mobility and to inform new devices about existing reservations, each device would still have to attempt to send a beacon in every superframe. If every device attempts to send a beacon in every superframe, the number of beacon slots will have to be considerably larger than the number of active devices in order to avoid frequent beacon collisions. This would create a significant and unnecessary overhead and would reduce the number of devices that can be supported. Even with a higher number of beacon slots than active devices, beacon collisions would be frequent and would thereby harm the mobility support significantly.

The essential feature(s) of the invention

Medium Access Protocol during a Beaconing Period

In order to overcome the described disadvantages of EDCA and the pure slotted Aloha beaconing scheme, the following new beaconing method, based on a modified slotted Aloha protocol, has been conceived:
In order to reduce the number of beacon (and thereby reservation) collisions it is foreseen that each device keeps sending its beacon in the same beacon slot in subsequent superframes. Surrounding devices, that can receive the beacon, should mark this beacon slot as occupied. Each device should select its beacon slot among the un-occupied beacon slots and access it in Slotted Aloha manner. This access method is identical to the Distributed Reservation Protocol (DRP) used for the access to data slots. No additional access protocol would have to be implemented and the DRP protocol and/or the slotted aloha engine could be re-used. Each device would just have to maintain one additional bitmap to store the occupancy of beacon slots as well as the number of the own beacon slot. A beacon slot status is changed from occupied to un-occupied, if no beacon has been received in the respective slots for n subsequent superframes.
In contrast to the old Beacon Collision Resolution Protocol, in a first embodiment of this invention, no information regarding the beacons of other devices is reported in the beacons. This reduces the size of the beacons and the complexity of the beaconing protocol significantly. However, with such a solution, beacon collisions might occur in hidden station scenarios, as beacon information is transmitted only to the direct neighbors and not to the neighbors' neighbors. Instead of avoiding such situations before they occur, it is foreseen in this embodiment that the collisions are resolved after they have occurred. A device that detects a collision (by the fact that an expected beacon is missing) can announce the collision in its beacon by including the MAC ID of the device in a collision information field. A device, which detects that its MAC ID is included in another device's beacon, has to change its beacon position in the subsequent superframe. A special bit in the beacon

is used to announce a forthcoming beacon position change in the subsequent superframe. This is required in order to allow the neighboring devices to distinguish between missing beacons due to intentional beacon position changes and missing beacons due to beacon collisions. In order to avoid that beacons are constantly colliding, in case that no other device is detecting the collision, it is furthermore prescribed that each device periodically changes its beacon position after m superframes.

In a second embodiment of this invention the beacon collisions in hidden station scenarios are avoided by including the locally stored bitmap, which signals the occupancy of beacon slots, in the own beacon. Note, that this inclusion of the beacon bitmap has been already proposed by Sony before.

In a third embodiment of this invention neither of the two above collision resolution mechanisms is applied. Instead, beacon collisions are not avoided completely, but their probability is simply reduced by changing the beacon position in every m-th superframe.

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Beacon Periods (BPs) Initialization

The Beaconing Period (BP) structure and channel access is described in [1]. A modified channel access is explained in the section above. In this section we describe initialization of beaconing periods.

Every device that intends to participate in communication with other devices shall send a beacon. When a device is turned on, scans for existing beaconing periods. The device may decide to join an existing beaconing period. In this case, a beacon is sent in one of the empty slots, using the rules specified in [1] or the modified protocol explained above.

A device may also decide to create a new beaconing period, for example, to create a new WUSB cluster. Creation of new BPs is not recommended, unless it is strictly necessary due to, for example, lack of empty slots in existing BP. The new BP shall not collide with existing BPs and/or DRP reservations.

At least 2 empty slots shall exist in a BP to allow new devices to join the network.

Co-existence of Multiple BPs

If a device decides to create a new BP, it shall announce the creation of the new BP in the already existing BPs. The new device shall send a beacon in the existing BPs and mark the time used by the new BP as a hard DRP reservation with priority = BP. Devices that receive beacons that include a DRP reservation with priority BP, include a duplicate of the reservation in its own beacon. The device keeps beaconing in the existing BPs until a duplicate of the reservation is received in other beacons.

It may also happen that multiple BPs need to co-exist due to mobility. When an “alien” BP is detected, a device shall announce the existence of an “alien” BP, and protect it, by including a hard DRP reservation in its own beacon with priority = BP.

If existing DRP reservations collide with a BP, the BP has the highest priority, and therefore other DRP reservations need to be renegotiated.

If two or more BPs collide, devices with colliding beacons need to search for empty slots. Optionally these devices may start a new BP in a “non-colliding” time.

Synchronization within a BP is achieved as explained in [1].

Peer devices shall beacon in the same BP. If a transmitter device communicates with devices that beacon in multiple (different) BPs, the transmitter device shall beacon in said multiple BPs.

When two or more BPs co-exist, devices may optionally switch to another BP. If a device switches to another BP, it shall keep beaconing in the original BP during "x" superframes in order to announce that it's switching BP. This is done through a special announcement field included in the beacon. A BP terminates and therefore the DRP hard reservation can be cleared when no beacons are heard during that BP.

If a device detects collisions of alien BPs, it may send a beacon within the colliding BPs and announce the collision. This is done trough a special announcement field included in the beacon.

Detailed description of how to build and use the invention

The new beaconing mechanism would be implemented in all devices, which implement the MBOA UWB physical layer as well as the new MBOA MAC protocol. The implementation would be done partly in hardware and partly in software. More details of the implementation can be provided in the final version of this application.

Applications of the invention

This invention can be used as access method in any wireless system. Its main intended application is to use it as beacon slot access mechanism for the new UWB MAC protocol. The UWB MAC protocol will be used by all devices that are labelled as MBOA UWB devices. These devices will serve WUSB, Consumer Electronics as well as various other applications.